8/PRTS

09/701223
529 'd PCT/PTC 27 NOV 2000
PCT/US99/11617

APPARATUS AND METHOD FOR TESTING A TELECOMMUNICATIONS SYSTEM

The present invention relates to a method and apparatus for testing a telecommunications system.

Conventional apparatus for testing telecommunications systems applies a test signal to the telecommunications system and, by analysing the response of the system to the test signal, calculates one or more parameters of the system in accordance with a chosen line model.

A problem with conventional methods is that it is not possible to determine the series line resistance of a transmission line in the system under test.

In accordance with a first aspect of the present invention there is provided a method of testing a telecommunications system, the method comprising;

1) applying a first AC test signal having a first signal frequency to the system and measuring the response of the system to the first test signal;

2) applying a second AC test signal having a second signal frequency different to the first signal frequency to the system and measuring the response of the system to the second test signal; and

3) calculating one or more parameters of the system from the responses measured in steps 1) and 2).

The first aspect of the present invention provides additional data which can be analyzed to calculate system parameters (e.g. electrical parameters such as resistance or capacitance) which have been previously difficult or impossible to determine - such as series line resistance.

The first and second AC test signals may be applied at the same time, in the form of a multi-frequency signal. However preferably the first and second test signals are applied at different times.

The wave form of the first and/or second test signal may be non-sinusoidal (for instance a square wave or saw-tooth wave) but preferably the test signals have a

substantially sinusoidal waveform. This simplifies the calculation procedure.

It is important that the method can test the telecommunications system quickly - this enables a number of lines within the system to be tested over a given period. Therefore preferably less than 5 cycles of each signal is applied to the system. In a preferred embodiment, two cycles of each signal are applied to the system.

Typically the test signals are each applied to the system through a known impedance. The voltage drop across the known impedance can then be used to calculate a characteristic impedance of the telecommunications system.

If additional data is required, then one or more additional test signals may be applied to the system. The one or more additional test signals may comprise AC test signals with a signal frequency different to the signal frequency of the first and second test signals. However preferably the or each additional test signal comprises a DC test signal.

Typically the system comprises first and second transmission lines (conventionally known as A and B lines). Conventionally an AC test signal is applied simultaneously to both lines (either in phase or in anti-phase) and the response of only one of the lines is monitored. In a preferred embodiment the step of applying a test signal and measuring the response of the system comprises:

a) applying the test signal to the first line and monitoring the response of the first line and the second line to the test signal; and
b) applying the test signal to the second line and monitoring the response of the second line and the first line to the second test signal.

By monitoring the response of both lines, additional parameters can be obtained.

In accordance with a second aspect of the present invention there is provided a method of testing a

telecommunications system comprising first and second transmission lines, the method comprising

1) applying a first test signal to the first line and monitoring the response of the first line and the second line to the first test signal;

2) applying a second test signal to the second line and monitoring the response of the second line and the first line to the second test signal; and

3) calculating one or more parameters of the telecommunications system from the responses measured in steps 1) and 2).

The second aspect of the present invention enables a number of system parameters to be calculated. In contrast with conventional systems, the response of both the first line and the second line is monitored.

The first and second signals may be DC signals, or alternatively the first test signal and/or the second test signal may comprise an AC signal. In a preferred example the signal frequencies of the first and second test signals are substantially identical. Alternatively, the signal frequency of the first and second test signals may be different.

The first and second test signals may be generated independently, but preferably they have a known phase relationship. This enables the parameters to be calculated more easily in step 3).

A number of embodiments of the present invention will now be described with reference to the accompanying drawings in which:-

Figure 1 is a schematic illustration of apparatus for testing a telecommunications system;

Figure 2 illustrates the remote test unit, exchange and telephone in more detail;

Figure 3 illustrates the functional structure of the remote test unit;

Figure 4 is a schematic diagram illustrating the arrangement of the line test unit;

Figure 5 illustrates part of the measurement cycle;

Figure 6 illustrates the full complex voltages measured by the AC measurement cycle;

Figure 7 is a first example of a line model;

Figure 8 is an enhanced line model;

Figure 9 is a line termination model, discussed in Appendix 4; and

Figure 10 is a third example of a line model.

Figure 1 is a schematic diagram of a system for remotely testing a telecommunications line. An operator station 1 is connected to a general controller 2 which inputs and outputs signals to/from a telecommunications medium 3 (which may comprise a PSTN or X.25 network). A telephone 6 is connected to a local exchange 5 via a land line 7. A remote test unit (RTU) 4 is connected to the exchange 5 in order to test the land line 7. Figure 1 illustrates a control path 8 and a test path 9.

As can be seen in Figure 2, the line 7 comprises a pair of lines 10,11 (configured as a twisted pair) known conventionally as "A" and "B" lines. An exchange feed comprising a 50V battery 12 is connected to the A and B lines 10,11 during normal operation via 200 ohm resistors 13,14. In order to test the line 7, the RTU control line 8 switches the A and B lines 10,11 over to the test line 9 (which in turn comprises a pair of input lines 15,16). The RTU communicates with the general controller 2 via a V.24 link (17) or 300 V.21 link (18).

The internal functional structure of the RTU 4 is shown in Figure 3. The A and B input lines 15,16 are connected to a line access unit 19 which controls the input and output of signals to/from the line 7. A line test unit 22 controls testing of the line 7, a tone generator 23 generates tone signals 24 which can be output onto the line 7, and voice modems 25,26 handle voice signals which can be communicated between the operator station 1 and telephone set 6. The RTU is controlled by a microprocessor 20 and data acquired is saved in a memory 21.

The line test unit 22 is illustrated in more detail in Figure 4. A pair of signal generators 30,31 generate sine wave signals which are amplified by respective amplifiers 32,33. The signals output by amplifiers 32,33 have a range of +/-200V and a bandwidth of 10kHz. The signal generators 30,31 are run synchronously from the same clock by a controller 34. This ensures that the signals have a known phase relationship. Each line has a respective set of output resistors 35-40 (each having a known resistance within a tolerance of 1%). Each output resistor has an associated switch 41-46 which can be closed by controller 34 to connect the associated output resistor between the amplifier and output line 47,48. Typical resistance values for the three output resistors on each line are 200,1M and 100K ohms. The voltage on line A is measured by a voltmeter 49 and the voltage on line B is measured by a voltmeter 50. The voltages are digitised by A-D converter 51 which samples at 12 kHz. Phase and RMS voltage values are calculated by processor 52 and stored in memory 53.

Referring to Figure 5, the line test procedure is as follows:

Step 1 - open all output resistor switches 41-46 and measure DC voltage on A and B lines.

Step 2 - adjust DC bias of amplifier 32 so that amplified signal is centred on line A DC voltage level.

Step 3 - adjust DC bias of amplifier 33 so that amplified signal is centred on line B DC voltage level.

Step 4 - set signal generators 30,31 to generate a DC signal.

Step 5 - close a selected one of the line A output resistor switches 41-43.

Step 6 - store DC voltages on voltmeters 39,50 in memory 53.

Step 7 - open selected line A switch and close a selected one of the line B output resistor switches 44-46.

Step 8 - store DC voltages on voltmeters 39,50 in memory 53.

Step 9 - set signal generators 30,31 to 2.75Hz.

Step 10 - after first cycle, perform digital fourier transform (at 2.75Hz) of signals from voltmeters 49,50 over second cycle and store amplitude and phase values in memory 53.

Step 11 - open selected switch 44-46 (line B) and close switch 41-43 associated with selected output resistor (line A).

Step 12 - after first cycle, perform digital fourier transform (at 2.75Hz) of signals from voltmeters 49,50 over second cycle and store amplitude and phase values in memory 53.

Step 13 - adjust frequency of signal generators 30,31 to 5Hz.

Steps 14-16 - repeat steps 10-12 at 5Hz.

The resulting AC data can be represented as four complex voltage values as illustrated in Figure 6, where:

V_{A1} is the voltage measured by voltmeter 49 (line A) with signal being applied to line A;

V_{B1} is the voltage measured by voltmeter 50 (line B) with signal being applied to line A;

V_{A2} is the voltage measured by voltmeter 49 (line A) with signal being applied to line B; and

V_{B2} is the voltage measured by voltmeter 50 (line B) with signal being applied to line B.

The four complex values can then be used to calculate four impedance parameters Z as defined below:

$Z_{11}=V_{ae}/I_a$ when line b is open;

$Z_{22}=V_{be}/I_b$ when line a is open;

$Z_{12}=V_{ae}/I_b$ when line a is open; and

$Z_{21}=V_{be}/I_a$ when line b is open;.

where

V_{ae} is the voltage on voltmeter 49 (ie. the voltage from line A to earth);

V_{be} is the voltage on voltmeter 50 (ie. the voltage from line B to earth);

I_a is the current on line 47 (line A); and

I_b is the current on line 48 (line B).

Since the voltages (V_a,V_b) output by the amplifiers 32,33 and the values (R_a,R_b) of the resistors 35-40 are known accurately, the currents I_a and I_b can be eliminated from the expressions for Z as follows:

$Z_{11}=R_aV_{ae}/(V-V_{ae})$;
$Z_{22}=R_bV_{be}/(V-V_{be})$;
$Z_{12}=R_bV_{ae}/(V-V_{be})$; and
$Z_{21}=R_aV_{be}/(V-V_{ae})$.

Once the Z parameters have been calculated as discussed above, they can be used to determine characteristics of the line 7 under test using an algorithm based on a selected line model.

One example of a suitable line model is illustrated in Figure 7. The series resistances of the lines 10,11 between the RTU 4 and the telephone 6 are represented by resistors R_1,R_2. The line termination at telephone 6 is represented by resistors R_5,R_6 and capacitors C_2,C_3. The leakage to ground from the A and B lines is represented by resistors R_3,R_4 and capacitors C_1,C_2. The problem with the line model of Figure 7 is that it is difficult to find ten independent equations based on conventional tests in order to calculate the ten line model parameters. Even if ten independent equations could be found, it would be difficult to solve the ten non-linear equations even by a numerical method.

The alternative line model of Figure 8 reduces the number of parameters to be identified by replacing the line termination parameters R_5,R_6,C_2 and C_3 with a single impedance value Z. In Figure 8 the series resistances of the lines 10,11 between the RTU 4 and the telephone 6 are represented by resistors r_1,r_2 and the leakage to ground from the A and B lines is represented by resistors g_1,g_2 and capacitors C_1,C_2.

A set of equations based on the enhanced line model of Figure 8 can be manipulated into a linear equation system

and a set of symbolic solutions obtained as set out in Appendix 1, Appendix 2 and Appendix 3 below.

Furthermore, the line termination parameters can also be calculated as set out in Appendix 4 below.

The calculated values of the parameters r_1, r_2, g_1, g_2, c_1, c_2 and z are stored at the RTU for later analysis or transmitted back to the operator station 1. The parameters can then be used to identify and characterise any faults on the line 7 such as a break in the line, fault to ground or fault to another line. Furthermore the parameters can be used to determine whether the line 7 is suitable for carrying different communication protocols such as ISDN,DACS,HDSL,CWSS or ADSL.

A further alternative line model is illustrated in Figure 10. It is possible to calculate the parameters of this model using a simplified measurement procedure which uses a DC measurement followed by a single AC measurement (ie. at only one frequency).

Although the line test unit 22 illustrated in Figure 4 is shown with two signal generators 30,31 and two sets of output resistors 41-46, it will be appreciated that a single generator and a single set of resistors could be used, and switched from one line to the other.